Nuclear Science Program in the Physics Division of Argonne National Laboratory

Report to NSAC
January 29, 2001

Scientific Programs:

- Operate the Argonne Tandem Linac Accelerator System (ATLAS) as a National User Facility for the low-energy nuclear physics community.
- Carry out a forefront nuclear physics research program in low-energy and relativistic heavy-ion physics.
- Perform advanced accelerator R&D with particular emphasis on the Rare Isotope Accelerator (RIA).
- Carry out a wide ranging program in nuclear theory spanning the frontiers of the field including QCD, meson-nucleon dynamics, and state-of-the-art many-body calculations of nuclear structure and reactions, particularly at the limits of isotopic asymmetry, stability and high spin.
- Carry out a targeted program in medium-energy physics focusing on the QCD substructure of hadrons and nuclei.
- Develop new experimental technologies, such as atom trap trace analysis to provide new opportunities in nuclear research.

Staff	FY01
Ph.D staff	32
Post-docs	17
Tech/Admin staff	45
Graduate Students	24
Undergrad/ Pre-college	54

Budgets(in as spent k$):

Category	FY00		FY01	
	Operations	Equipment	Operations	Equipment
ATLAS Operations	5635	325	5598	335
Heavy Ion Research	5185	1031	4963	666
Theory	910		905	
Medium Energy	2770	100	2856	97
Accelerator Improvement		400		393
Base Nuclear Budget	14500	1856	14322	1491
RIA R&D	700		1412	
Total Nuclear Budget	15200	1856	15734	1491

ATLAS

Number of Users in FY2000: **236 on-site during year including 69 students**
64% U.S., 36% Foreign

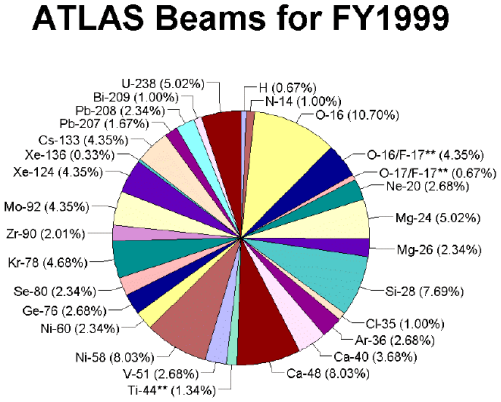
Number of R&D Hours of beam on target in FY2000: **5460**

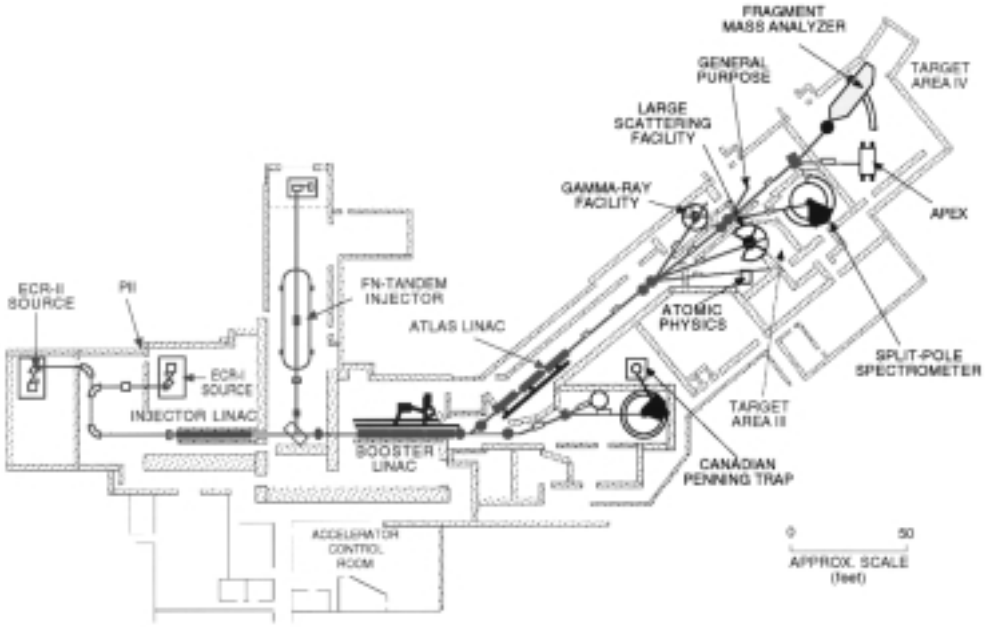
Operating Efficiency in FY2000: **94.9%**

Number of Experiments in FY2000: **51**

ATLAS Capabilities:

•beams of all masses from hydrogen through uranium
•beam energies comparable to internal energies of the nucleus -- with maximum energies of 18 MeV/u for light nuclei to 9 MeV/u for the heaviest – all above the Coulomb barrier.
•beam currents ranging from several particle microamperes for light projectiles to hundreds of particle nanoamperes for heavier elements. Newly demonstrated ability of ATLAS to accelerate several charge states simultaneously.
•exceptional beam quality with beam diameters of 1mm diameter or less: transverse emittances of ~ 1 π mm-mrad and longitudinal emittances of ~ 20 π keV–ns on target leading to excellent energy resolution (1/1000 or better) and time resolution as low as 100 ps..
•precisely controllable and variable beam energies (from hundreds of keV/u to 18 MeV/u), including the ability to operate in accel-decel mode.
•highly efficient ion sources, suitable for separated isotopes, coupled with exceptional transmission of the beam through the accelerator system.
•great flexibility in being able to switch beams and/or energies rapidly.
•100% CW duty cycle with beam pulses at the RF frequency, 82.4 ns apart; a fast beam sweeper offers the capability of removing any number of micro pulses.
•the ability to produce and accelerate high-quality, exotic beams with the two-accelerator method and the in-flight technique (e.g. ^{17,18}F, ^{44}Ti, ^{56}Ni).

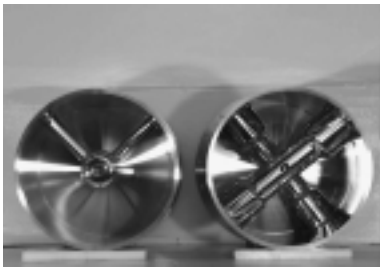




RIA Accelerator Concept and R&D

Many of the crucial new accelerator technologies needed for RIA have been conceived and demonstrated at ANL.

- ATLAS; world's first superconducting ion accelerator
- Multi-beam driver
    1. New low-beta superconducting cavities
    2. Multiple Charge State acceleration concept proposed and demonstrated
- Liquid lithium targets for 100 kw heavy-ion beams
- Two-step neutron generator
- Fast gas catcher for rare isotopes: high efficency, ms extraction times, excellent emittance, independent of ion chemistry
- CW RFQ for 1^+ ions with high mass
- Efficient $1^+ \rightarrow 2^+$ stripping at very low velocity



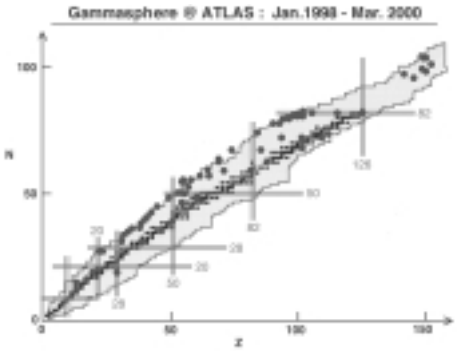
Heavy-Ion Research

Research Emphasis:

- Structure of nuclei at the limits of proton-neutron asymmetry, charge and angular momentum.
- Measurements of nuclear reactions of astrophysical significance with exotic beams via both the two-accelerator and in-flight techniques.
- high precision tests of fundamental interactions to search for physics beyond the standard model.

Current Experimental foci:

- Precise mass measurements of unstable nuclei with the Canadian Penning Trap.
- Structure of proton emitters.
- Structure of transuranic nuclei.
- Breakout from the hot CNO cycle.
- Study of important reactions associated with the r-p process and supernovae. (waiting points, ^{44}Ti production)
- Search for signatures of n-p pairing.
- Radiative capture in heavy-ion reactions.
- Properties of superdeformed nuclei (structure, feeding, decay).
- The PHOBOS experiment at RHIC.

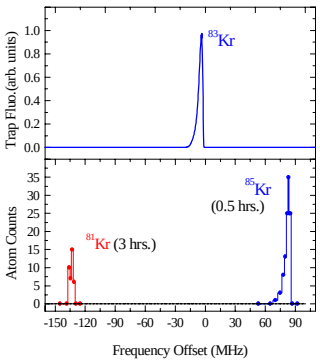


Theory

- Quark degrees of freedom in hadrons --- continuum QCD with Dyson Schwinger equations to study mesons and baryons in light and heavy quark sectors, including applications at finite temperature and density.
- Meson and baryon-resonance degrees of freedom in nuclear systems at intermediate energies --- building a common framework for γN, πN and NN reactions and investigating nuclear dynamics with Δ and N* excitations.
- Nucleon degrees of freedom with realistic NN and 3N interactions. ---ab initio calculations of few-body nuclei, light closed-shell nuclei, nuclear and neutron star matter and astrophysical reactions--- all with the same nuclear forces.
- Complex nuclei and reactions with effective interactions --- structure and reactions of halo nuclei, heavy ion reactions near the Coulomb barrier, and nuclei at high spin and deformation --- relevant to many ATLAS and other experimental programs.

Medium-Energy Physics

- Quark structure of matter from hard scattering probes
  - Deep inelastic scattering (HERMES)-- spin carried by gluons, valence and sea quarks in the nucleon, nuclear effects: the HERMES effect
  - Drell-Yan reactions (FNAL)—flavor structure of the nucleon sea, parton energy loss in cold nuclear matter.
- Hadronic structure of matter from exclusive electromagnetic interactions (JLAB)
  - Electron scattering with a hadron in coincidence – search for color transparency and the pion excess in nuclei.
  - Exclusive photoreactions—scaling and polarization in photoreactions.
- Atom traps for trace isotope analysis (ATTA)
  - First demonstration of method for krypton isotopes
  - Applications in environmental science, climatology, medicine, nuclear structure and solar neutrino detection



Physics Division, Argonne National Laboratory --Responses to NSAC Questions:

1 What are the main new research initiatives which are being proposed for your facility during the coming years? Are there specific facility upgrades, which you are pursuing to enhance the competitiveness of your facility through the next decade?

- Our primary upgrade direction is the construction of the Rare Isotope Accelerator.
- In the short term we are developing increased capability for high beam currents of heavy-ions for transuranic research and increased capability for the acceleration of selected radioactive beams.

2 The LRP Charge to NSAC explicitly asks us to consider the FY2001 Budget as the baseline budget for the field. Is this, in fact, a budget level which will allow your facility to operate in a lean, but competitive and cost effective manner, in the years to come? If not, what are the essential additional resources, which you would require, and the benefits that would accrue from them?

- Our present budget is insufficient to continue ATLAS operations and research at the present level. Given the 10% decrease in our base budget over the past few years we are forced to plan to significantly reduce ATLAS operations and productivity (by 25%). With a restoration of this 10% decrease, ~ 1.3 M$ we can continue to operate ATLAS 7 days a week.

3 What is the balance of your research program between work at your local facility and outside user efforts at other facilities in the US or abroad? Has this balance changed since the last LRP, and do you expect it to evolve further in the coming years?

- Our heavy-ion research program is roughly 80% based at ATLAS, with user experiments primarily at Gammasphere and RHIC. This balance has remained relatively constant over the past 5 years, fluctuating with the siting of Gammasphere, and we expect it to remain so. Roughly 80% of the medium-energy program is based at other facilities.

4 Are you satisfied with your ability to attract and support top quality graduate students?

- We find that a significant number of excellent graduate students are attracted to our programs and we are determined to support them. As a national laboratory we are closely linked to the issues experienced by our university colleagues in attracting graduate students. The broad research program of a national user facility provides an attractive feature for many students.

5 Are there other aspects of your facility and programs, which are unique or particularly noteworthy?

- Our facilities and programs have many noteworthy features, which we have tried to emphasize in this presentation. These include the unique capabilities of ATLAS as the premier low-energy heavy-ion accelerator and world leading scientific programs in heavy-ion research, nuclear theory, medium-energy physics and accelerator physics. These programs lead to unique accelerator and instrumentation initiatives (e.g. RIA R&D, ATTA, GARBO, APT).